Idaho National Engineering and Environmental Laboratory

Thermal-Hydraulic Capabilities for Analyzing Generation IV Reactors

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Outline

- *The origin of the ATHENA code*
- *Capabilities for Gen IV design analysis*
- *Ongoing Gen IV activities*
- *Conclusions*

ATHENA is a version of the RELAP5 code developed for the USNRC and DOE

- *Funded by DOE programs*
- *Extended capabilities:*
  - *Multidimensional hydrodynamic model (cylindrical or Cartesian)*
  - *Integrated multidimensional nodal kinetics model (NESTLE)*
  - *Models for non-water coolants*
  - *Graphical user interface*
  - *Coupling capability*

ATHENA models to support Generation IV initiatives

- *Working fluids (Pb-Bi, CO_2, He, Na, NaK, Li-Pb)*
- *Constitutive models*
  - *Forced convection heat transfer*
    - *Rod bundles in liquid metal*
    - *SCW (interim models)*
    - *Pebble bed*
  - *Pressure drop correlations*
    - *Heated wall effect on friction factor for SCW*
    - *Pebble bed*
  - *Oxidation of graphite pebbles and blocks in air and steam*

ATHENA models to support Generation IV initiatives (cont'd)

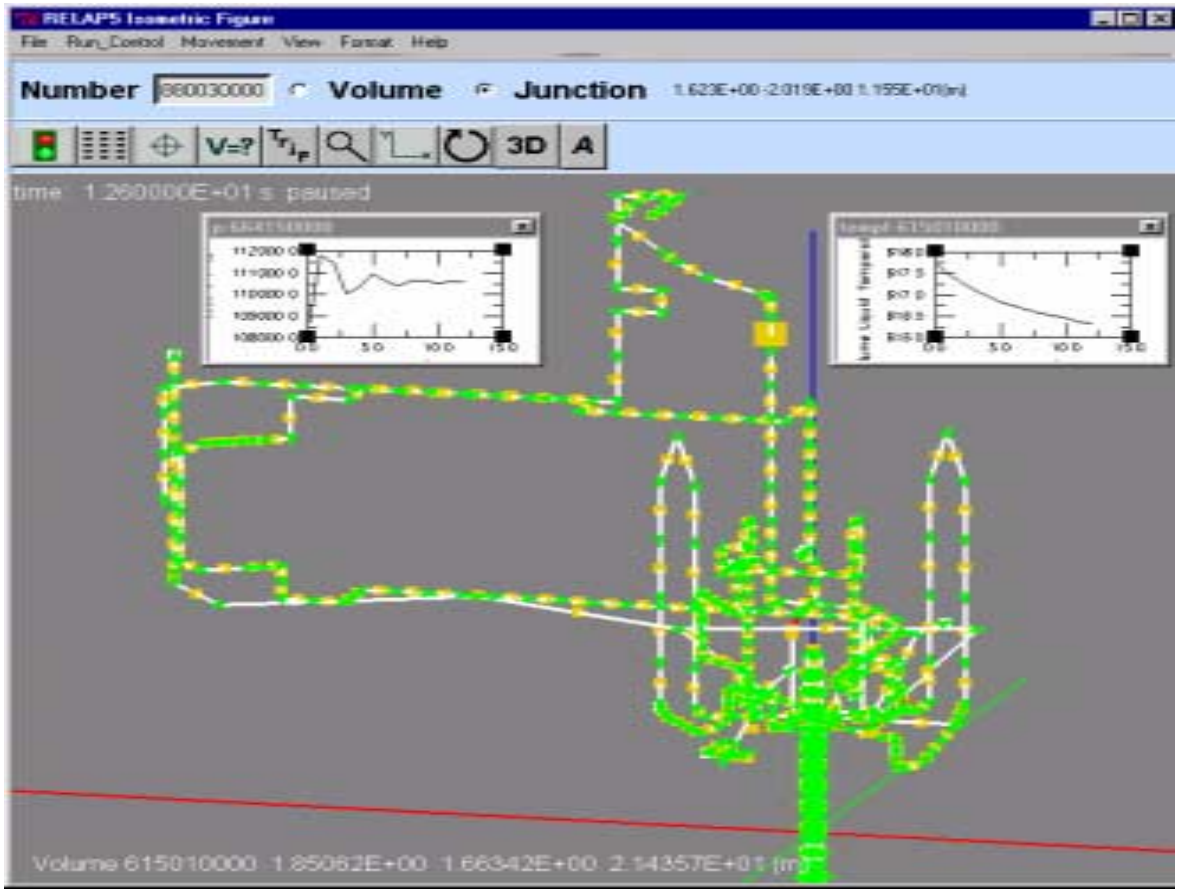
- *Enhancement of the turbine component model*
- *Development of a compressor component model**
- *Development of a diffusion model to represent air ingress into the core (affects graphite oxidation)**

**Ongoing*

ATHENA has useful support features

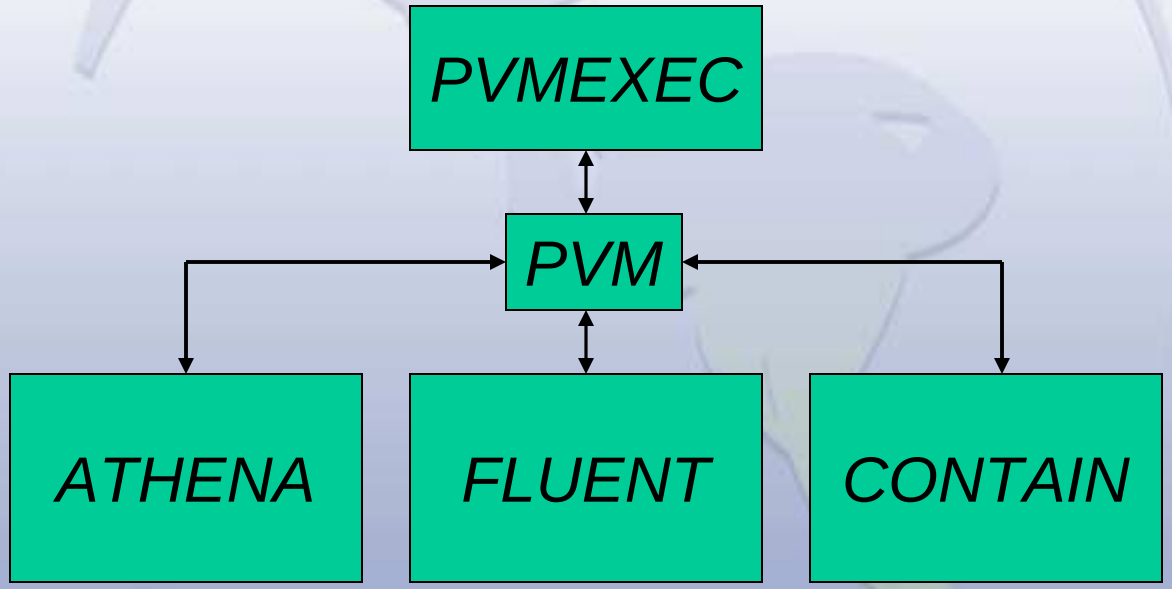
- *Graphical user interface (RGUI) for ease of execution and analysis*
- *Code coupling capability enables linkage of ATHENA to other codes*
- *XMGR5 for post-process plotting*
- *Pygmalion for creation of steady-state input decks*
- *Code executes on UNIX (DEC, HP, SUN, SGI) and PC (Windows) platforms*

The Graphical User Interface generates a 3D image directly from the normal input data…



and dynamically displays computed results in real time or in playback mode

An Executive program controls the coupling of ATHENA to other codes using PVM



Synchronous or Asynchronous coupling

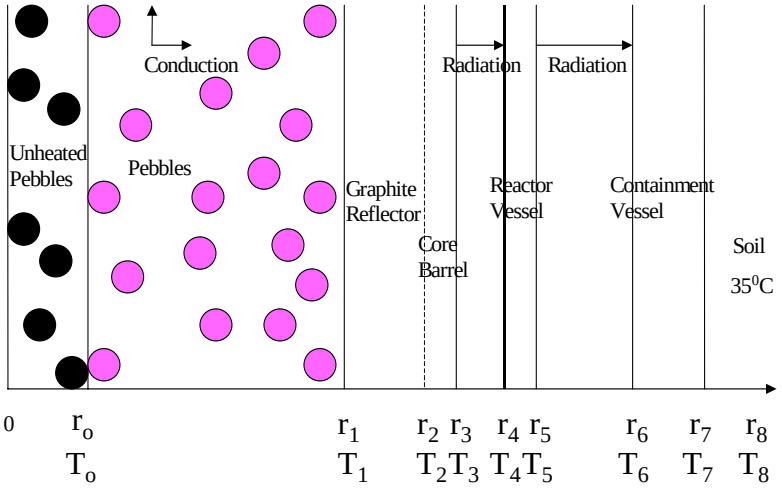
Analyses of Gen IV designs are underway using ATHENA

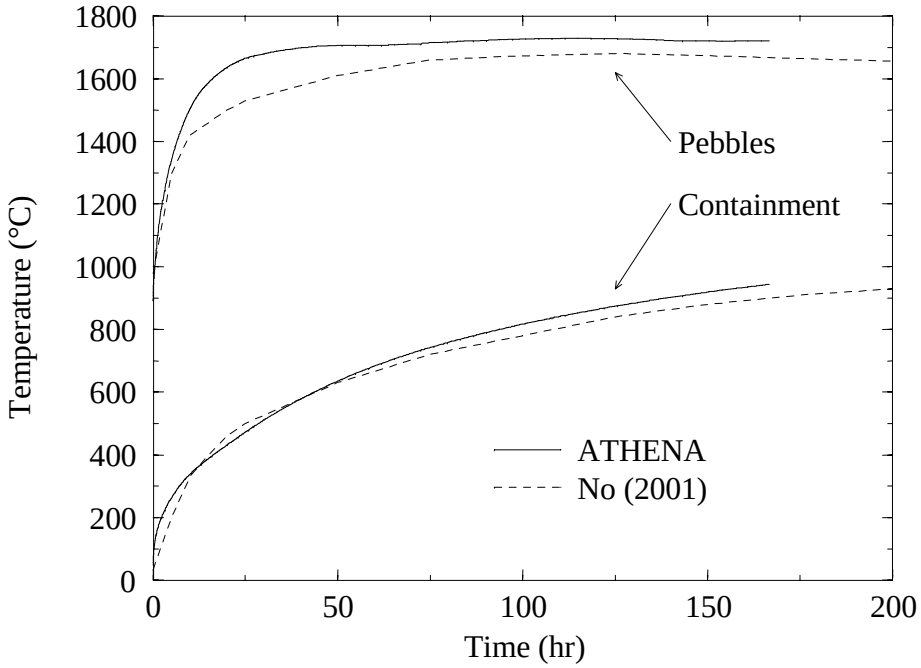
Scoping calculations include:

- *SCWR*
  - *Safety system design*
  - *Solid versus water rod moderation*
- *Pebble Bed GCR*
  - *Decay heat rejection during LOCA*
- *Lead-Bismuth Reactor (with MIT)*
  - *Effectiveness of RVACS during station blackout*

Decay heat removal in Pebble Bed during LOCA

Conduction Enclosure Model





ATHENA has most of the necessary models for pebble fuel

- *One-dimensional spherical heat conduction*
- *Heat transfer and pressure drop correlations for porous media*
- *Oxidation of graphite in steam and air*
- *Point or multi-dimensional reactor kinetics*
  - *Multi-dimensional model supports Cartesian or hexagonal geometry, not cylindrical*
- *No pebble cracking model*

ATHENA can represent most of the safety features of the PBMR

- *Simulates the important heat transfer mechanisms for the depressurization accident*
  - *Convective to pebbles*
  - *Heat conduction enclosure model is used to calculate the heat flux across pebbles*
  - *Radiation enclosure model is used to calculate radiation between different heat structures, such as between vessel and containment walls.*
- *Detailed internal flow studies will require CFD modeling*

ATHENA has models to represent the balance of plant

- *Pipes*
- *Valves*
- *Heat exchangers*
  - *Different fluids allowed on different sides of the heat exchanger*
- *Pressurizer*
- *Pumps*
- *Turbine*
- *Compressor (model under development)*
- *Control systems*

Conclusions

- *ATHENA is a flexible and general tool for thermal-hydraulic simulation of nuclear reactor systems*
- *ATHENA already has most of the models needed to perform calculations of PBMRs and other Generation-IV designs*
  - *Additional decay heat models are required for new fuel types*
- *ATHENA should be validated against appropriate experimental data*
- *ATHENA has been linked to other analysis tools (Fluent, CONTAIN, etc), which greatly expands the capability of the code*